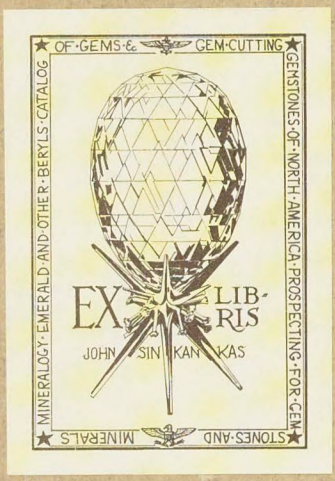
Spence

The Wilberforce Radium Occurrence
H. S. Spence and R. K. Carnochan

Radioactive Fluorspar from Wilberforce, Ontario.
Frank L. Hess

Petrology of the Richardson Radioactive Deposit, Wilberforce, Ontario.
R. B. Rowe


OF·GEMS·&·GEM·CUTTING
GEMSTONES·OF·NORTH·AMERICA·PROSPECTING·FOR·GEM·STONES·AND·MINERALS
MINERALOGY·EMERALD·AND·OTHER·BERYLS·CATALOG
EX LIB-RIS
JOHN SINKANKAS

Dr Dale . with compliments
R. A. Spence

Reprinted from the Canadian Mining and Metallurgical Bulletin; being part of the TRANSACTIONS *of the Canadian Institute of Mining and Metallurgy for 1930*
Subject to Revision. *All Rights Reserved.*

gem apatite p. 17 xls uraninite p. 19. 1930
V. 33, pp. 34-73

The Wilberforce Radium Occurrence*

BY HUGH S. SPENCE AND R. K. CARNOCHAN**

(Annual General Meeting, Toronto, Ont., March, 1930)

INTRODUCTORY

THIS paper deals with an occurrence of radium ore near Wilberforce, Haliburton county, Ontario, upon which development work has recently been undertaken and which seems more likely to prove of commercial grade than any other deposit of radioactive minerals hitherto found in Canada. This occurrence is sometimes called the Richardson property, after Mr. W. M. Richardson, the discoverer, and will be so referred to in the present paper.

Occurrences of radioactive minerals are not uncommon in eastern Canada, and a number are recorded in the literature. The earliest of such references is probably that in *Geology of Canada, 1863*, where is mentioned an occurrence of uraninite at Mamainse, on the east shore of lake Superior. The mineral was first described by J. L. Leconte, in 1847, under the name of coracite, and was said to occur in a two-inch vein at the contact of trap and syenite. Search for this locality in recent years has proved unsuccessful.

Obalski, in 1894, mentions (1) the occurrence of uraninite at a mica mine near Murray Bay, Que. In 1903, Obalski records (2) tests made on this uraninite by Rutherford and the Curies and the determination in it of the then newly-discovered element radium. In 1901, he mentions (3) the occurrence of uraninite at the Villeneuve mica mine, on the Lievre river, and of samarskite at the Maisonneuve mica mine, in Berthier county.

---

*Published by permission of the Director, Mines Branch, Department of Mines, Ottawa.

**Mines Branch, Department of Mines.

(1) Report of Commissioner of Crown Lands, Province of Quebec, 1894, p. 99.

(2) Annual Report of Mining Operations in the Province of Quebec, 1903, pp. 65-68.

(3) Mica in the Province of Quebec, Department of Colonization and Mines, Quebec, 1901, pp. 18-21.

Most of the earlier discoveries of radioactive and rare-earth minerals in Canada were thus made in pegmatite dykes in Quebec province, where they were found during mica-mining operations.

Later, other discoveries of these minerals were made in similar association in pegmatites worked for either mica or feldspar, both in Quebec and Ontario, and now the list of localities where radioactive minerals are known is a fairly large one. All of such occurrences, however, are in normal granite pegmatites, the minerals being found usually disseminated irregularly and in small amount through the dyke mass or in small pocketty zones in the dykes (1).

Up to the present, the only occurrence of a radioactive mineral that it seemed possible might have commercial possibilities has been that of euxenite, which was found in some quantity in a feldspar quarry in South Sherbrooke township, Lanark county, Ont., in 1917. A small shipment of ore from this deposit was sent to the Mines Branch in 1919 for concentration tests and from it a few hundred pounds of concentrates were made; however, no attempt at commercial production was made by the owners. Euxenite is not particularly rich in uranium (7 to 9 per cent U_3O_8), and accordingly there is comparatively little market interest in it as a source of radium.

It should be noted that a radioactive and rare-earth mineral content is not by any means peculiar to Canadian pegmatites. It is in association with this type of rock that such minerals are usually found the world over, and in some countries, notably in Norway and Sweden, as well as in India, Madagascar, and Tanganyika, pegmatites occur that are probably far richer in radioactive minerals than any found in this country prior to the Wilberforce discovery. It is not known, however, that except in Madagascar, any serious attempt at mining such pegmatites for their radium-bearing minerals has ever been made, though small amounts have been recovered during mica- and feldspar-mining operations. Most of such material, however, is believed to have found its way as specimens into mineralogical collections and not to have been used as a commercial source of radium. It does not seem likely, basing the belief on what appears to be the general world occurrence of pegmatitic radio-

(1) For further information on the occurrence in Canada of radioactive minerals, see Geol. Surv. Can., Summ. Rep., 1921, Pt. D., pp. 51-70; Summ. Rep., 1923, Pt. C,I pp. 6-20.

active minerals, that the ordinary run of pegmatites in Canada can be seriously regarded as a potential, commercial source of radium ore.

The Richardson deposit, while associated with pegmatite, differs in several important respects from other recorded occurrences of such minerals, either in Canada or (as far as the writer is aware) in other countries (see page 15), and the amount of uraninite thus far obtained from small surface workings greatly exceeds that yielded by all Canadian mica and feldspar mines. The total quantity of uraninite, amounting to several hundred pounds, thus far taken from the property, and all obtained practically from the surface, may be regarded as a promising indication that the occurrrence will prove rich enough to work; and, accordingly, it has seemed of interest to describe the main features of the deposit and the results of development to date.

The data presented are based on visits by the first-named author to the property in August and November, 1929, supplemented by information supplied by the operating company, The Ontario Radium Corporation, 539 Confederation Life Building, Toronto, and on the results of tests conducted by the Ore Dressing Division of the Mines Branch, at Ottawa, on a carload shipment of ore. Mr. Carnochan had charge of these tests, and the radioactive determinations on the concentrate samples were conducted by Dr. H. V. Ellsworth, of the Division of Mineralogy, Geological Survey. The chemical analyses of the concentrate were made by Mr. R. A. Rogers, of the Ore Dressing Division, Mines Branch.

LOCATION OF DEPOSIT, TOPOGRAPHY, ETC.

The deposit is situated on lots 4 and 5 in concession XXI of the township of Cardiff, Haliburton county, about 1½ miles east of the village of Wilberforce, on the I. B. and O branch of the Canadian National railways. It lies one-half mile south of the Wilberforce-Bancroft road and of the railway, on the north edge of the ridge bordering the valley through which the railway runs. It can be reached by automobile from either the east or west, the distance by road from Toronto being about 150 miles, and from Bancroft 20 miles.

The Ontario Radium Corporation owns a total of 456 acres, comprising the above-mentioned lots and also lots 4, 5, and 6 in concession XXII, immediately to the north

ONTARIO RADIUM CORPORATION LTD
QUEBEC
St Lawrence River
MONTREAL
OTTAWA
BOSTON
ATLANTIC OCEAN
NEW YORK
PHILADELPHIA
COCHRANE
NORTH BAY
BANCROFT
WILBERFORCE
LINDSAY
COBOURG
KINGSTON
HALIBURTON
HOWLAND
WHITBY
TORONTO
Lake Ontario
BUFFALO
PITTSBURG
CLEVELAND
Lake Erie
DETROIT
TOLEDO
CINCINNATI
CHICAGO
Lake Michigan
Lake Huron
Georgian Bay
SAULT STE MARIE
Lake Superior

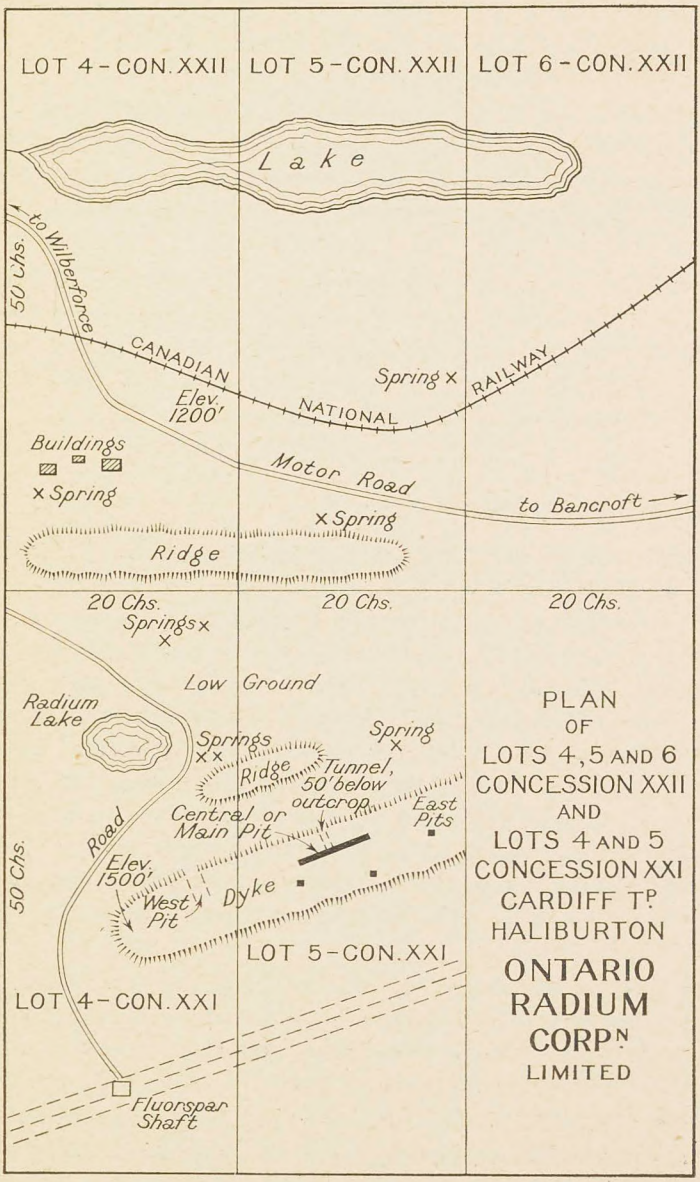


Figure 2.—Plan of property, showing approximate location of workings, etc. (Not to scale).

Topographically, the region is one of medium relief. The altitude at the railway, north of the deposits, is 1,200 feet, from which point southward the ground rises gently in a series of benches to an elevation of 1,500 feet at the main pit.

The overburden at the point of discovery is generally light, consisting of seldom over 20 inches of sandy or gravelly soil, and rock outcrops are abundant. The part of the property comprising the main discovery site has been burnt over and supports only a light growth of small timber.

A small lake occupies a depression on the second bench below the pits, being fed by springs issuing from the ridge. Several such springs have been located and are regarded by the Company as assets of importance, since their water has been tested and found to be strongly radioactive, as is also the water of the lake.

HISTORY

The first discovery of radium ore in the Wilberforce district was made in 1922 by Mr. W. M. Richardson, a prospector and miner with Alaska and Yukon experience, who had come to Wilberforce in connection with the finds of molybdenite that had been made near that place, and had taken up residence about one-half mile northwest of the site of the present operations. In the course of prospecting the district, Mr. Richardson found a heavy, black mineral in surface outcrops of pegmatite at different points on the property, and having obtained a sample of Joachimsthal pitchblende, identified this mineral as uraninite. He, therefore, took up the mining rights on lots 4 and 5 in concession XXI, and on lot 4 in concession XXII, and proceeded to open up a number of small prospect pits and trenches.

A sample of the uraninite sent by Mr. Richardson to Ledoux and Company, of New York, for assay, was reported by them to contain 58.35 per cent of uranium oxide (U_3O_8), equivalent to a radium content of 147 milligrams of radium per ton.

Late in 1922, Dr. W. G. Miller visited the property and described it briefly in *The Canadian Mining Journal* of January 11th, 1924.

In 1923, Mr. Charles Baycroft was engaged by a Toronto syndicate to make an examination and report on the deposit. Mr. Baycroft opened a 30-foot trench on one of the westerly outcrops, and

from this sent a 200-pound sample to Dr. T. L. Walker, at the University of Toronto. Concentration tests were run on this sample, and Dr. Walker furnished the following report:

"In making a preliminary test on the ore, I found that the material coarser than 10 mesh did not lend itself to concentration. The finer material, from 10 mesh down to fine sands, gave a fairly clean-separation on the Wilfley table and apparently will give little trouble in concentration.

"Values from electroscopic measurements on the head sample and concentrates were as follows:

Original heads	2.88	milligrams of radium per short ton
Concentrates:		
Through 10 mesh on 40 mesh	7.82	"
Through 40 mesh	5.70	"
Slimes	0.24	"

The above syndicate did not proceed with development, and except for further minor prospecting by Mr. Richardson, there was no other development until the present owners acquired the property in 1927.

In 1926, Dr. G. E. Richards, Director of the Department of Radiology, Toronto General Hospital, had visited the property and secured samples of the ore and spring waters. With respect to the latter, Dr. Richards reported that three samples of water taken at various points all showed distinct radioactivity.

In 1927, Mr. M. D. Kennedy made a report on the property to the present Company, who in 1929 commenced their first development work. Up to this time, attention had mainly been focussed on several outcrops of pegmatite that represented the points of original discovery of uraninite. Two of these outcrops lie fairly close together on lot 5, concession XXI, while a third, upon which most work had been done, lies about 2,000 feet to the west of the above, on lot 4. Prospecting of the ground between these two points early in 1929 led to the discovery of a well-defined break or vein, quite distinct from anything found hitherto. It is upon this lead that attention has since been centred and upon which work is proceeding at the present time. All of the three shipments of ore made to the Mines Branch in 1929, and upon which tests were run, came from this vein.

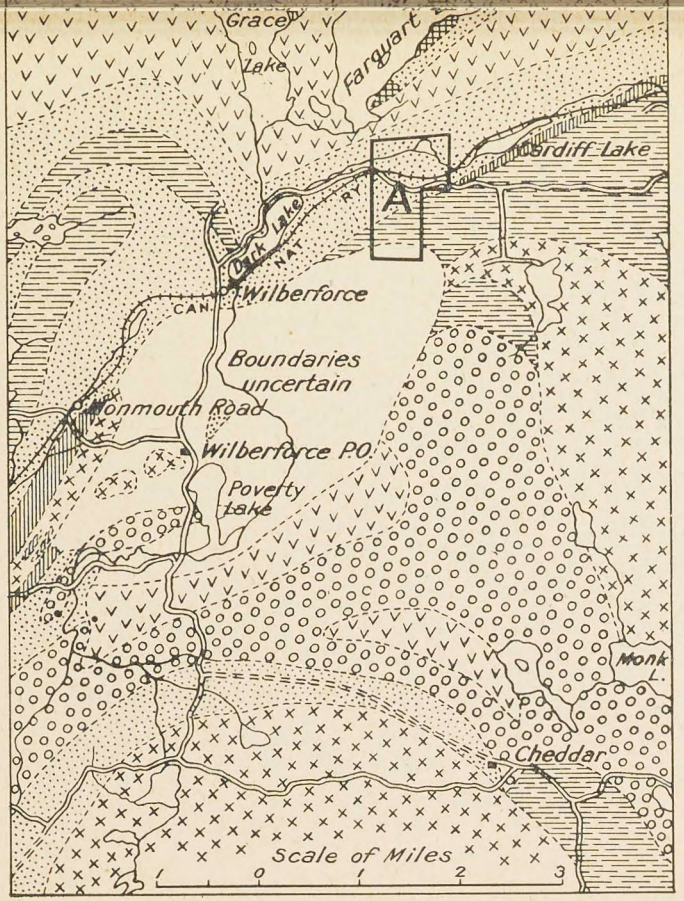
In addition to shipping ore to the Mines Branch for test, the Company has recently forwarded a large sample of picked uraninite to the Imperial Institute, in London. As a result, they have enlisted the interest and services of that body, and also of the British and General Radium Corporation, in the matter of further development and of marketing of products, or of the eventual extraction of radium from the ore. In the last connection, the Company are highly desirous that Canada should receive the fullest benefit from the possession of a domestic supply of this precious element. In the event, therefore, of their deposit proving commercial, they wish, if this be possible, to have the extraction done in this country, and the recovered radium made available for Canadian hospitals, etc.

GEOLOGY

The only detailed geological report on the Wilberforce district is that of Adams and Barlow, published in 1908 (1). No special mention is made in this report of the area immediately around the deposit under consideration, and at that time the only local occurrences of economic minerals known were a few small deposits of mica and phosphate.

The map (Figure 3) accompanying the report shows the site of the uraninite discoveries to consist of a narrow east-west band of sedimentary gneiss, much invaded by granite (pegmatite) dykes. A parallel belt of white crystalline limestone occupies the whole of the valley below the deposit to the north, the gneiss-limestone contact crossing the north half of lots 4 and 5. This contact probably is more or less parallel to the pegmatite with which the ore is associated and not far north of it. An area of several square miles immediately to the south and west of the gneiss band is left blank as to geology. Surrounding this area lies a comp'ex assemblage of bands and islands of crystalline limestone, amphibolite, gneiss, nepheline syenite, and granite, the latter in part massive and in part gneissic. A large batholith of granite is shown south of the deposit, its northern rim being about five miles distant. This batholith connects by a narrow neck with a second mass of more gneissic granite lying to the northeast. From this, a tongue is shown extending westward to within about a mile of the property. The

(1) Geology of the Haliburton and Bancroft Areas, Geol. Surv. Can., Mem. No. 6.



LEGEND

- White crystalline limestone.
- Gneiss (probably altered sedimentary material) or quartzite.
- Amphibolite.
- Gabbro and diorite.
- Gneissic granite with many amphibolite inclusions
- Gneissic granite.
- Nepheline syenite and associated alkali-syenite
- A — Ontario Radium Corporation Limited

Figure 3.—Geological map of Wilberforce district.
(After Adams and Barlow)

many areas of pegmatite shown invading the rocks adjacent to these granite masses are possibly genetically related to them, though this is only theory. The pegmatite with which the uraninite is associated contains little or no free quartz, and the same holds good for a number of other pegmatites examined by the writer in Cardiff and adjacent townships. In some instances, these pegmatites cut, or are in close proximity to, areas of nepheline syenite, and for this reason, as well as on account of certain conspicuous peculiarities in mineral composition, the writer is inclined to view them as pegmatitic phases of syenite rather than of granite.

With respect to the geology of the uraninite deposit itself, the following notes are based on an examination made by the writer in September, 1929, supplemented by information supplied in part by the owners and in part taken from Mr. Baycroft's report made in 1924.

WEST PIT:

Mr. Baycroft's report deals with that part of the property where the first discovery of uraninite was made in 1922 and upon which most of the development work was done prior to 1929. At this point is situated the most westerly opening on the deposit, a narrow open cut about 6 to 8 feet deep and 50 feet long, entirely in pegmatite. The cut is at right angles to the strike of the pegmatite, which has an approximately east and west direction. The opening does not disclose either of the walls of the dyke, which, according to Mr. Baycroft's report, is about 350 feet wide.

The character of the pegmatite is generally uniform for the whole length of the cut. The rock consists essentially of a coarse-grained, buff-coloured feldspar, probably orthoclase, though no samples were taken for analysis. There are numerous irregular, miarolitic cavities, some of them of considerable size, their walls being lined with well-developed feldspar crystals. Free quartz is conspicuously absent from the rock. Here and there through the dyke mass occur masses and large crystals of magnetite, the most abundant metallic mineral. Small amounts of molybdenite and chalcopyrite also occur, as well as biotite mica and zircon. Only at one place, in the east wall of the cut, is any uraninite now visible. At this point, there is a small mass of uraninite enclosed in feldspar, the latter carrying yellow and orange incrustations of uranium

salts. According to the owners, however, a considerable amount of disseminated uraninite was encountered when the cut was made. This would appear to be borne out by the tests made by Dr. Walker on the 200-pound sample from the opening sent to him by Mr. Baycroft. This sample is stated to be representative of 30 feet of the cut and to have yielded over one per cent of U_3O_8.

EAST PITS:

Several small pits have also been opened on outcrops of what is presumably the same pegmatite at a point about 2,000 feet east of the above opening. The rock here is essentially similar to that in the west cut, being a medium- to coarse-grained syenite pegmatite; in one of the pits it contains much fluorite. Of interest, is the occurrence in one of the exposures of a narrow stringer of fine-grained syenite porphyry cutting the pegmatite.

Small inclusions of uraninite are said to have been found in these easterly openings, but none were seen by the writer.

MIDDLE PIT:

This opening, situated between the west and east pits, represents the latest work done, and has been made on a discovery made in 1929. It lies 1,600 feet east of the west pit and 400 feet west of the easterly openings. Stripping operations were started here in the spring of 1929 on a small outcrop, and have disclosed a well-defined lead that has been uncovered for a length of 150 feet. This lead is in pegmatite and parallels the strike of the dyke. Its full length has not yet been determined, but it outcrops again at a point 300 feet east of the stripping, and is exposed there for a width of 12 feet. It can also be traced for a short distance west of the stripping, but appears to be pinching out in this direction. It is probably safe to assume a total length of at least 500 feet. The width is greatest at the east outcrop, where it measures 12 feet. At the stripping, the greatest width is 8 feet and the average about 5 feet, though there are several narrow horses of pegmatite in the east end. The above measurements relate to the width between the outermost exposed walls. The gneiss country rock is only visible on the hanging-wall, the footwall being pegmatite. Insufficient stripping has been done on the footwall side to show whether any parallel leads exist, but this will be determined by the tunnel now being driven to tap the lead from a point 50 feet down the slope below the outcrop.

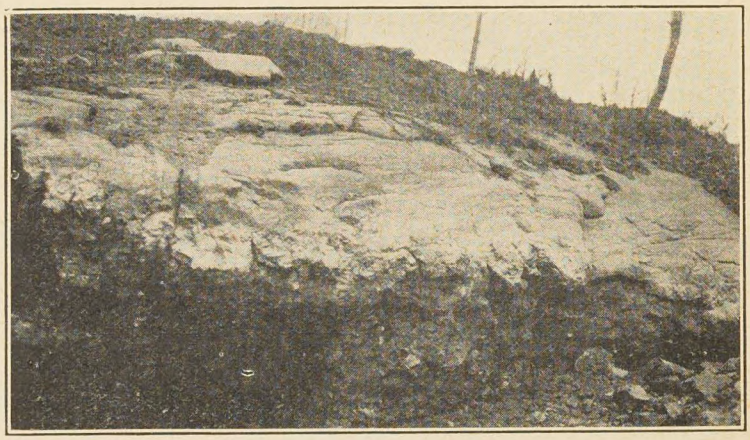


Figure 4.—Part of vein from which ore shipment was made to the Mines Branch for test.

The stripped surface is gneiss, with a thin band of pegmatite bordering the vein. (Photo. taken November, 1929).

The dip of the lead at the surface is about 45° south, or into the hill, steepening to 70° at the bottom of a 20-foot pit sunk near the west end of the stripping.

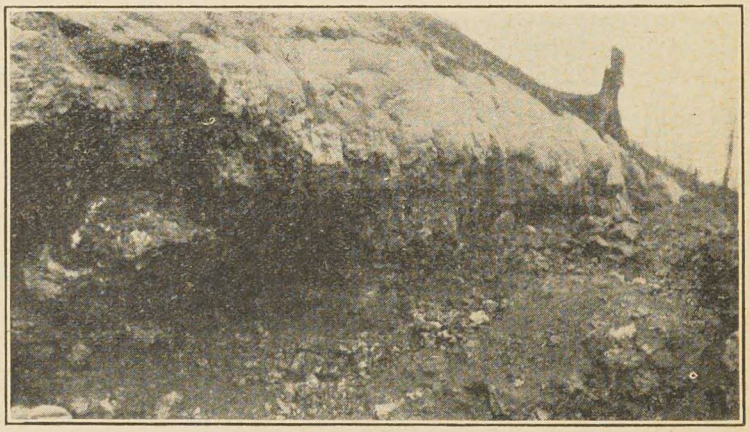


Figure 5.—West portion of vein, showing 75 feet of surface working.

The carload of ore shipped to the Mines Branch came from the pit in the foreground. (Photo. taken November, 1929).

The lead occurs in pegmatite at its contact with the enclosing gneiss and seems to have the character of a longitudinal, miarolitic cavity of unusual form and extent. Only a skin of pegmatite a few inches thick occurs on the gneiss hanging-wall (see Figure 4) and from it project numerous well-formed feldspar crystals up to 6 inches in length. The footwall of the lead, as far as is visible, is also pegmatite, but there has been insufficient stripping to give any idea of the total width of the dyke here.

The westerly 75 feet of stripping shows a single lead, 5 to 8 feet wide, but for the remaining 75 feet the vein is split into four or

Figure 6.—East portion of vein-stripping, about 75 feet in length, showing tongues of vein separated by narrow horses of gneiss and pegmatite.

Mr. Richardson, the discoverer of the deposit, is in the middle foreground. (Photo. taken November, 1929).

five tongues of irregular width, but ranging from 1 to 4 feet. These tongues are separated by narrow, 1- to 2-foot horses of gneiss and pegmatite, the walls of which are also lined with feldspar crystals (Figure 6). This portion of the lead, therefore, represents a series of long, parallel miarolitic pockets or cavities, which toward the west run together into a single wider one. At the outcrop 300 feet east of the stripping, where there is 12 feet of lead exposed, there are no horses visible, the lead being uniform from wall to wall.

In its general character, the Richardson pegmatite resembles other pegmatitic bodies found in Cardiff and adjacent townships. As a type, these are quite distinct from the ordinary run of granite

pegmatites so common in eastern Canada and are apparently peculiar to the Wilberforce district. The writer is inclined to view them as syenite, rather than granite pegmatites, and to regard them as genetically related either to the nepheline syenite of the region or to the large batholithic masses that occur in Cardiff and Monmouth townships. These latter, it is true, are shown on Adams' and Barlow's map as granite, but in their report the writers note that the rock is never rich in quartz and often grades over into syenite.

A notable occurrence of another such pegmatite is found about one mile east of the Richardson property, where there is a large development of purple fluorite, mixed with calcite, apatite, hornblende, etc.; this deposit was worked at one time for fluorite. On the southwest end of the Richardson property, also, several small prospect pits were opened some years ago on fluorite outcrops. Another occurrence lies about 10 miles to the southeast, in Faraday township, where cavities in pegmatite contain calcite and enormous crystals of black mica, as well as large apatite crystals and fluorite. The writer has examined several other such deposits in the region, all generally similar in type. Some of them carry small traces of radioactive minerals, but none are in any way comparable in this respect to the Richardson deposit.

In their general character, these pegmatites possess a marked similarity to the mica- and phosphate-bearing pyroxenites of the Ottawa district. These pyroxenites, which may be considered as basic counterparts of the Wilberforce syenite pegmatite, often contain large, irregular cavities lined with well-formed pyroxene crystals and carry a filling of calcite, in which are scattered large apatite and mica crystals: they do not yield radioactive minerals.

For the purpose of comparison, the principal characteristics of the two rock types are outlined below:

BASIC TYPE

Locality	Ottawa district.
Rock	Pyroxenite pegmatite.
Character	Medium- to coarse-grained rock in the form of irregular dykes and consisting mainly of grey to green pyroxene. Titanite and scapolite are common accessory constituents. Often contains large, irregular, pocketty cavities, lined with pyroxene crystals.
Mineral filling of cavities	Pink calcite, in which lie free crystals of phlogopite mica and apatite, often of very large size.

ACID TYPE

Locality	Wilberforce district.
Rock	Syenite pegmatite.
Character	Medium- to coarse-grained rock in the form of irregular dykes and consisting mainly of pinkish-buff feldspar. Zircon is a common accessory mineral. Often contains large pocketty cavities, lined with feldspar crystals.
Mineral filling of cavities	White or pinkish calcite and dark purple fluorite, in which lie large crystals of apatite, biotite mica, hornblende, magnetite, and uraninite.

The close structural similarity exhibited by these two rock types, and the fact that both often carry crystals of apatite and mica in a calcite filling of pocketty cavities, provides strong evidence that the pyroxenites are of igneous, intrusive origin, rather than metamorphosed sediments, as has often been believed.

The filling of the Richardson lead consists mainly of massive fluorite and calcite. Neither of these minerals was observed in the form of free crystals. Fluorite predominates in the greater part of the lead, but there are local enrichments of calcite, when the two minerals are present in about equal amounts: there is often an approach to banded structure. Scattered through this calcite-fluorite filling occur, in order of abundance, crystals of apatite, hornblende, magnetite, biotite, and uraninite.

At the outcrop, there has been considerable leaching of the calcite by surface waters, resulting in the formation of open cavities within the lead. These cavities contain a certain amount of dark, reddish-brown, earthy residue, and in this are often found loose crystals or lumps of uraninite.

From a search of the literature, the only recorded occurrence that in any way resembles geologically and mineralogically the Richardson ore-body appears to be a deposit at Wölsendorf, in Bavaria. At the latter locality, dark purple, foetid fluorite is found in a lead with autunite, torbernite, and uranophane, all alteration products of pitchblende, traces of which also occur.

MINERALS OF THE DEPOSIT

Apatite.—Apatite occurs in considerable amount as free crystals in the calcite-fluorite matrix. The crystals are sometimes of considerable size, ranging up to 30 pounds in weight (Figure 7). Several dozen loose individuals were taken by the writer from a small

Figure 7.—Mr. J. A. McAndrew, one of the Directors of the Ontario Radium Corporation, holding a large crystal of apatite taken from the vein.

pocket, the calcite of which had been leached out by surface waters. The prism faces are well developed, but good terminations are rare, the ends of the crystals seeming to have been attacked, and being pitted and rounded. There is apparently no development of compact, massive apatite.

The colour is usually brownish-green to brown or yellow. Like the apatite of other similar deposits in the district, and in contrast to that of most pyroxenite deposits, the mineral is clear and glassy and exceedingly brittle. Clear fragments of considerable size and without visible flaws can often be picked from broken crystals.

An interesting feature of the apatite of the Wilberforce district is that, where crystals exhibit terminal faces, there is always a conspicuous development of the basal plane. This is sometimes so pronounced that the crystals appear to have almost square ends. The basal plane is seldom, if ever, found on the pyroxenitic apatite of the Ottawa region.

Biotite.—Biotite mica is stated to occur, sometimes in large plates, in the massive pegmatite of the west pit. It was not observed in noteworthy amount in the main, or middle, pit.

Calcite.—Calcite is one of the principal constituents of the lead. It is mostly rather fine-grained and has a faint pinkish colour. As in the pitchblende veins of Czechoslovakia, the colour deepens to a brownish-red in close proximity to uraninite nodules or crystals, and thus dark-coloured calcite serves as an indicator for uraninite.

Feldspar.—Feldspar, of a buff to reddish cast, is the principal constituent of the pegmatite with which the uraninite is associated. It is medium- to coarse-grained and probably is predominantly orthoclase (potash feldspar). There is possibly a certain amount of soda or lime-soda feldspar also present, but no information on this point, based on analyses or microscopic examination, is available.

The walls of the miarolitic cavities in the pegmatite are lined with well-formed feldspar crystals which often attain a length of several inches. This mineral always forms part of the pegmatite proper and it is not found as free crystals in the calcite-fluorite filling of cavities, as are the apatite, hornblende, magnetite, etc.

Fluorite.—As one of the principal constituents of the filling of cavities in the pegmatite, fluorite is possibly the most interesting gangue mineral present.

When fresh, its colour is always of a dark reddish-purple to violet shade, deepening in close proximity to uraninite to almost black. In this respect, it resembles the fluorite of other deposits of

radioactive minerals throughout the world, and it may be taken as established that the dark colour is due to radioactive emanations. The colour of all such fluorites fades on exposure to light and the mineral eventually becomes colourless.

When disseminated through calcite, the fluorite is in the form of small, shapeless grains. It also forms bands or stringers, and is then usually fine-textured to dense and compact. The last type is always found in close association with uraninite, and thus serves as an indicator for that mineral.

A peculiarity of such compact fluorite is that it gives off a strong odour when crushed or freshly-broken. This odour is of practical service to the workmen as an additional indication that they are breaking into a pocket of uraninite. The smell resembles that of ozone and is believed to be due to free fluorine.

The conspicuously dense texture and almost black colour of the fluorite accompanying the uraninite, and the reddish colour assumed by the calcite in similar association, would prove a useful aid in preliminary rough-sorting of the ore, enabling the rich material to be readily separated in the pit from the lower-grade or barren gangue.

Hornblende.—Large, free crystals of hornblende, sometimes over 12 inches across, frequently occur in the calcite-fluorite filling of the main, or middle, lead.

Magnetite.—Magnetite is fairly abundant, occurring as large crystals or irregular masses in miarolitic calcite-fluorite. It was observed in greatest amount in the west and middle pits.

It is frequently intergrown with uraninite, and sometimes also with apatite and hornblende.

Molybdenite.—Small traces of molybdenite are stated to have been found in the massive pegmatites of the west pit.

Uraninite.—This, as far as known, is the only radioactive mineral occurring in any important amount on the property. Small amounts of its alteration products, in the form of orange and yellow incrustations of uranium salts, as well as traces of torbernite, the copper uranium phosphate, are found in association with it, but these are hardly of commercial significance. Up to the present, none

of the radioactive, rare-earth minerals—not infrequently found in the ordinary granite pegmatites of eastern Canada—have been reported here.

The uraninite occurs as well-formed crystals and as nodular lumps. The crystals are often of unusual size, frequently measuring one inch or more across. They are of cubic habit, usually more or less modified by the octahedron. The lumps range from small individuals the size of a pea to masses weighing several pounds.

In the massive pegmatite of the west pit, the uraninite is stated to have been found chiefly associated with black mica and often enclosed in mica 'books'. Unlike its occurrence in the middle pit, it does not seem to occur here in miarolitic cavities.

In the lead of the middle pit, the uraninite crystals and masses occur scattered through the calcite-fluorite filling, apparently without any regular system, but, as noted above, always in close association with dark purple fluorite. The same distribution holds at the outcrop 300 feet east of the middle pit.

As regards the relative abundance of uraninite in the deposit, Mr. Baycroft's report states that a sample taken across 30 feet of pegmatite at the west pit yielded a little over one per cent U_3O_8, equivalent to 28.56 pounds of uraninite per ton. The carload shipment sent to the Mines Branch, and representative of the ore of the middle lead, showed a recoverable uraninite content of 4.56 pounds per ton.

Two complete analyses of the uraninite have been made and are given below. The first is by E. W. Todd (1) and the second by H. V. Ellsworth (2). Both analyses were made on selected, clean mineral, and it is interesting to note that they differ considerably in uranium content. The sample analysed by Ellsworth is noted by him to have consisted of severely altered material, to which fact is attributed the low UO_2 content as compared with that of the sample analysed by Todd. Much of the uraninite mined during 1929, and examined by the writer, was observed to be similarly altered, the outer portions, both of crystals and lumps, consisting of a blackish-green, earthy material soft enough to be readily rubbed off by the fingers. The alteration is especially pronounced in the uraninite taken from

(1) Contributions to Canadian Mineralogy, University of Toronto Studies, 1924, p. 43.

(2) Geol. Surv. Can., Summary Report 1923, Pt. CI, p. 20.

leached cavities in the lead and would seem to have been effected by surface waters. The uraninite broken out of fresh fluorite or calcite has a much fresher and more lustrous appearance and probably more nearly approaches in composition that analysed by Todd, which came from the massive pegmatite in the west pit. Its specific gravity is given as 9.082. No figure is given by Ellsworth for the sample analysed by him, but determinations on two specimens—one a crystal and the other a massive lump—from the shipment sent to the Mines Branch in 1929 showed a mean of 8.83.

ANALYSES OF URANINITE FROM WILBERFORCE, ONTARIO

	I By E. W. Todd	II By H. V. Ellsworth
UO_2	45.18	13.55
UO_3	24.90	52.04
ThO_2	11.40	13.56
PbO	10.40	11.05
Ce_2O_3, etc	1.82	1.85
Y_2O_3, etc	2.74	1.24
Fe_2O_3	0.58	0.47
Al_2O_3	—	0.11
SiO_2	0.43	0.58
TiO_2	—	0.001
CaO	0.28	0.25
MgO	0.19	0.07
MnO	0.04	0.003
He	0.35	—
H_2O at 100°C	0.61	1.49
H_2O above 100°C		0.11
CO_2	—	0.67
SO_4	—	0.58
P_2O_5	—	0.04
F, alkalis	—	present
Loss on ignition	—	4.42
Insoluble	—	0.67
Total	98.92	98.334*
Equivalent to U_3O_8	69.71	61.64
Specific Gravity	9.082	not stated

*Less Loss on Ignition.

It may be noted, in passing, that the mineral uraninite is of scientific interest as enabling the geological age of the rocks in which it occurs to be calculated from the contained lead-uranium ratio. Such calculations based on Todd's analysis show an age for the Wilberforce pegmatites of 1,239 million years. Ellsworth's analysis indicates 1,299 million years. The difference is possibly to be accounted for by the probability that altered uraninite may yield a somewhat higher lead ratio than fresh mineral from the same occurrence.

Zircon.—Zircon is a minor rock-forming constituent of the pegmatite dyke, in which it occurs as small crystals measuring about 1/8 by 3/8 inches. It appears to have rather a zonal distribution, being quite abundant in some parts of the rock while not visibly present in others.

DEVELOPMENT WORK

Previous to 1929, the largest opening made for uraninite on the property was the west pit, a trench 50 feet long by 6 feet wide and about 6 to 8 feet deep. This was entirely in massive pegmatite containing scattered miarolitic cavities, and from it a few pounds of uraninite have been obtained.

Some distance south and west of this opening, there are several small pits, also in massive pegmatite, which were made in search of fluorite: these are not known to have yielded any uraninite.

The east pits consist of three or four small, shallow openings on outcrops of pegmatite, in which traces of uraninite are stated to have been found.

The middle pit, opened in 1929, is the most important working. It lies 400 feet west of the east pits and 1,600 feet east of the west trench, on the strike of a line joining these workings. Stripping of a light dirt cover has disclosed a well-defined east-west lead for a distance of 150 feet (Figure 8). This lead lies between pegmatite walls, and the calcite portion of its filling has been dissolved at the surface, resulting in the formation of numerous pocketty cavities. It is widest at a point about 30 feet from the west end of the stripping, and here an inclined pit, 6 feet square and 20 feet deep, has been sunk on the dip. The width here is about 8 feet, and the dip at the surface 50° south, increasing to 70° at the bottom of the pit. Lumps

and crystals of uraninite were encountered from top to bottom of this pit, scattered through the calcite-fluorite filling and also loose in leached cavities in the latter.

The carload of ore sent to the Mines Branch in October, 1929, was taken from the lead at a point a few feet east of the above pit. To secure this ore, the lead was worked from the surface to a maximum depth of 15 feet and over a length of 20 feet (Figure 5). Horses of pegmatite encountered were left in place, only vein-filling being shipped.

Figure 8.—View of vein, looking west from east end of stripping.
Total length shown is about 150 feet. (Photo. taken November, 1929).

It was originally intended to drive a tunnel into the hill from a point about 80 feet below the west pit, with the idea of cross-cutting the pegmatite and possibly striking other parallel leads. A start was made on this work, but the results of surface operations at the middle pit proving so encouraging, it was decided to drive the tunnel from a point below this pit and about 50 feet down the hill from it. Work is now proceeding here, and provided that the dip of the ore-body remains constant, it is expected that the ore-body will be struck at about 90 feet. The tunnel will facilitate mining operations and provide drainage for the upper workings; it will also test the ground north of the main lead, about which nothing is known, but in which it is thought other parallel leads possibly may occur.

The Company has thus far installed no equipment on the property, and only two or three men have been employed.

TESTS BY THE MINES BRANCH ORE DRESSING DIVISION

Three shipments of ore, in all, were received by the Mines Branch from the Ontario Radium Corporation.

The first shipment was received on July 9th, 1929, and consisted of two lots, each containing 40 bags and weighing about 2,000 pounds. These lots were numbered 1 and 2 and were taken from the west and east ends, respectively, of the discovery, corresponding to the west and east pits, as described in this paper.

The second shipment, received on August 22nd, 1929, consisted of a bag of 50 pounds of hand-picked uraninite, both lumps and crystals. This lot was numbered 3, and was taken from the main, or middle, pit, as described in this paper.

The third shipment, received on November 12th, 1929, comprised 603 bags of ore, weighing 71,596 pounds, and one bag containing 80.5 pounds of hand-picked uraninite, in the form of lumps and crystals. This shipment, numbered lot 4, came, like lot number 3, from the middle pit, and is understood to be representative of the main lead on the property. The bag of clean uraninite is stated to have been picked out by hand during mining of the ore.

Considerable laboratory work was conducted on the material of these various shipments, but only the results of the large-scale test made on lot number 4 are given here, since this was the only shipment that could be considered properly representative of the ore and from which useful data from the commercial angle could be expected.

LOT NO. 4

CHARACTER OF ORE:

The ore consisted of uraninite in a gangue of purple fluorite, calcite, apatite, magnetite, hornblende, biotite mica, and feldspar. The relative abundance of the gangue minerals was approximately in the order indicated. Very little uraninite was visible. The hand-picked uraninite was mostly clean mineral and contained only a relatively small amount of adhering gangue.

WEIGHTS

Gross weight of 603 bags of milling ore, wet	71,595.5	pounds
Tare	1,205.0	"
Net	70,390.5	"
Moisture at 1.786 per cent	1,257.0	"
Net weight of milling ore, dry	69,133.5	"
Ore not milled, dry	89.5	"
Total ore milled, dry	69,044.0	"
Milling ore received, dry	69,133.5	"
Hand-picked uraninite, dry	80.5	"
Total ore received, dry	69,214.0	"

TREATMENT OF MILLING ORE:

The ore was crushed in a gyratory and Symons disc crusher, and then screened on a 12-mesh Newaygo screen. The plus-12-mesh was crushed in a small set of rolls in closed circuit with the screen. A head sample was taken from the minus-12-mesh.

The balance of the minus-12-mesh was classified in a Richards launder classifier into three sizes. The coarsest size was tabled on a large Wilfley table; the medium size on a one-quarter size Butchart table; and the finest size was first thickened in a Callow cone and then tabled on a one-quarter size Wilfley table. Each of the three tables made a magnetite-uraninite concentrate.

The table concentrates were dried and run separately over an Ullrich magnetic machine, using a very low current in order to lift only magnetite. The magnetic products were very clean magnetite, and the non-magnetic were mostly fluorite with some uraninite.

The Ullrich non-magnetic products were re-tabled separately and good uraninite concentrates were obtained.

RESULTS OF TREATMENT OF MILLING ORE

(Weight of ore milled: 69,044 pounds)

TABLING:	
Coarse table concentrates	1,702 pounds
Medium " "	160 "
Fine " "	42 "
Total " "	1,904 "
MAGNETIC SEPARATION OF TABLE CONCENTRATES:	
Coarse Ullrich non-magnetic product	245 pounds
Medium " "	42 "
Fine " "	16.5 "
Total " "	303.5 "
RE-TABLING OF ULLRICH NON-MAGNETIC PRODUCTS:	
Coarse table concentrates	79 pounds
Medium "	4.31 "
Fine "	1.31 "
Total "	84.62 "

These concentrates were analysed for U_3O_8 with the following results:

Product	Weight	Per cent U_3O_8	Pounds U_3O_8
Coarse	79 pounds	44.44	35.11
Medium	4.31 "	52.62	2.27
Fine	1.31 "	56.14	0.74
Total	84.62 "	45.05	38.12

The above concentrates were recovered from 69,044 pounds of ore. From the total of 69,133.5 pounds of milling ore received, there would have been recovered 84.73 pounds of concentrates. From the total ore received (=69,133.5 pounds of milling ore plus 80.5 pounds of hand-picked uraninite=69,214 pounds), there would

be recovered by milling 84.73 pounds of concentrates. Therefore, from one ton of ore there would be obtained by milling:

CONCENTRATES FROM MILLING ORE, PER TON

Weight	*Per cent U_3O_8*	*Pounds U_3O_8*
2.448 pounds	45.05	1.103

The hand-picked uraninite was re-picked, and from the 80.5 pounds received, 64.75 pounds of clean uraninite were obtained. The residue of 15.75 pounds was crushed in a small set of rolls to all pass 20-mesh and was screened on 40 and 100. Each of the 3 sizes obtained was tabled on a small Wilfley table. The table concentrates were dried and run through the Ullrich machine to remove magnetite. Very clean uraninite concentrates were obtained in this way.

RESULTS OF TREATMENT OF HAND-PICKED ORE

(Weight of ore treated: 80.5 pounds)

PICKING:

Hand-picked uraninite received	80.50 pounds
Re-picked clean uraninite	64.75 "
Residue	15.74 "

MAGNETIC SEPARATION OF RESIDUE:

− 20 + 40 Ullrich non-magnetic product	3.69 pounds
− 40 + 100 " " "	2.92 "
− 100 " " "	1.80 "
Total " " "	8.41 "

The concentrates obtained were analysed for U_3O_8 with the results shown below. No analysis for U_3O_8 was made on the re-picked uraninite, but it was assumed to run 69.0 per cent. This figure was obtained by considering it to be 95 per cent clean and to contain 72.44 per cent U_3O_8, this being the content of a clean piece of uraninite from the same property analysed by Dr. Ellsworth. The assumed figure is probably nearly the actual, since it is reasonable to suppose that the re-picked uraninite would be slightly higher in U_3O_8 than the best concentrate obtained, that is, rather better

than 67.48 per cent, which was the value obtained for the coarse Ullrich product:

Product	Weight	Per cent U_3O_8	Pounds U_3O_8
− 20 + 40	3.69	67.48	2.49
− 40 + 100	2.92	67.28	1.96
− 100	1.80	67.32	1.21
Re-picked	64.75	69.00	44.68
Total	73.16	68.81	50.34

The above products were obtained from 69,214 pounds of ore, equivalent, per ton of ore, to:

CONCENTRATES FROM HAND-PICKED ORE, PER TON

Weight	*Per cent U_3O_8*	*Pounds U_3O_8*
2.114 pounds	68.81	1.454

TOTAL RECOVERIES, PER TON OF ORE

From	Weight	Per cent U_3O_8	Pounds U_3O_8
Milling ore	2.448 pounds	45.05	1.103
Hand-picked ore	2.114 "	68.81	1.454
Total	4.562 "	56.05	2.557

The uranium content of the concentrates from one ton of ore would be:

$2.557 \times 0.8481 = 2.169$ pounds.

The amount of radium contained in the concentrates from one ton of ore would be:

$$\frac{2.169 \times 453.59 \times 1000 \times 3.3}{10{,}000{,}000} = 0.3247 \text{ milligrams*}.$$

At $70 per milligram, the value of the radium contained in the concentrates from one ton of ore would be $22.73.

CONCLUSIONS

The ore is easily concentrated and the concentrates obtained are of good grade.

The tests showed a value of $22.73 for the radium contained in the concentrates obtained from one ton of ore. Whether the ore is commercial will depend on: the tonnage available; the cost of mining and milling; the cost of chemical treatment of the uraninite concentrates; the amount of uranium and radium in treatment; and the price obtainable for the refined products.

No data are available on which to base estimates of cost and losses in the chemical treatment of uraninite for the recovery of uranium and radium: the figures used in the next section are those adopted by the owners of the property.

COMMERCIAL POSSIBILITIES

The results of the work thus far conducted on the property, particularly that done during 1929—which has proved the existence of a well-defined uraninite-bearing lead, believed to be at least 500 feet long, and in places 10 to 12 feet wide—cannot but be considered as encouraging, as far as a supply of ore is concerned. While little can be said at this juncture regarding the probable downward persistence of this ore-body, the fact that it appears to represent a marginal deposit along a large pegmatite body, of which it forms an integral part and to which it is genetically related, suggests that it very possibly extends to a considerable depth. Being of miarolitic character, it bears a striking resemblance to the pyroxenitic calcite-apatite-mica bodies of the Ottawa region, some of which have been

---

*NOTE: The factor used $\left(\frac{3.3}{10{,}000{,}000}\right)$ is based on a radium content in uranium of 3.3 parts in 10 million. Authorities differ as to the exact figure.

mined to depths of over 500 feet without exhaustion. Such bodies are, however, often pronouncedly pocketty, and pinch and swell very irregularly.

From the angle of development, the deposit enjoys the advantage of being situated close to rail and on a surface that could hardly be bettered for easy and cheap mining. Lying along the brow of a ridge sloping almost directly from the outcrop, it is so placed that in the event of a mill being built, ore would fall into the bins by gravity. There is a hydro-electric power site capable of producing 500 h.p. within two miles of the property.

The ore, as shown by the large-scale test made by the Mines Branch, is easily crushed and concentrated, and only limited mill equipment, consisting of crusher, rolls, classifier, and tables, is required to make a uraninite-magnetite concentrate. This can be readily treated on a magnetic separator, with the production of a uraninite tailing that, on re-tabling, yields a clean product.

In addition to the radium value, there is the value of the uranium. The value of the associated thorium is problematical, since the world's supply of this element is believed to be supplied entirely from treatment of the mineral monazite, large supplies of which are available. The thorium oxide content of 1 ton of the pure uraninite, also, based on the market price of $130 per ton, is only $16.25, giving a negligible value per ton of ore.

The uraninite seems to vary somewhat in its uranium and radium content, as shown by the analysis of selected samples by Todd and Ellsworth. The uraninite content of the deposit may also be expected to prove somewhat variable. The Company has prepared estimates of values based on Todd's and Ellsworth's analyses and on an average content of 5 pounds of uraninite per ton of ore; the figures are shown in columns I and II of Table I. In column III are added for comparison the figures yielded by the shipment of ore made to the Mines Branch. The value of the radium content has been calculated on a basis of $70 per milligram, which is the present market quotation. The cost of extracting the radium has been placed by the Company at the figure of $20 per milligram, which is believed to be very much higher than what it would actually be. The cost of extraction from the Congo ores is reported to be around $5 per milligram. The cost of recovery of uranium has been estimated by the Company at $1.50 per pound, which, also, is believed to be very much higher than what it would be in actual practice.

TABLE 1

CONTENTS AND VALUES*

	I		II		III	
	Content	Value $	Content	Value $	Content	Value $
UO_2 in uraninite	45.18 per cent		13.55 per cent			
UO_3 " "	24.90 " "		52.04 " "			
Equivalent U_3O_8	69.71 " "		61.64 " "			
@ 90 per cent	62.74		55.48 " "			
U_3O_8 per ton of uraninite	1,255 pounds		1,109 pounds			
" " " ore	3.14 "		2.77 "		2.56 pounds	
Uranium element per ton of uraninite	1,064 "	2,660	940.4 "	2,351		
" " per ton of ore	2.66 "	6.65	2.35 "	5.88	2.17 "	5.43
@ 90 per cent	2.39 "	5.98	2.11 "	5.29	1.95 "	4.89
(Value based on price of $2.50 per pound)						
Radium per ton of uraninite	159.3 mg.	11,151	140.7 mg.	9,849		
" " " " ore	0.40 "	27.87	0.35 "	24.62	0.3247 mg.	22.75
@ 90 per cent	0.36 "	25.08	0.32 "	22.16	0.29 "	20.46
(Value based on price of $70 per milligram)						
Total value of uranium and radium:						
Per ton of uraninite		13,811		12,200		
" " " ore		31.07		27.45		25.35

*Column I: Figures based on analysis of uraninite by E. W. Todd, 1924, and on a uraninite content in the ore of 5 pounds per ton.

Column II: Figures based on analysis of uraninite by H. V. Ellsworth, 1923, and on a uraninite content in the ore of 5 pounds per ton.

Column III: Figures based on analysis of uraninite concentrates by R. A. Rogers, 1929, and on a U_3O_8 content in the concentrates of 2.56 pounds per ton. (Results of Mines Branch test).

TABLE II

CONTENTS, VALUES, AND COSTS PER GRAM OF RADIUM RECOVERED

Tons of ore	Contents and Values				Total value, $	Costs			Total cost, $	Value less Cost	
	Radium		Uranium			Mining and concentrating at $10 per ton $	Extraction of radium, at $20 per mg. $	Extraction of uranium, at $1.50 per pound, $		Total $	Per ton $
	Content, grams	Value, $	Content, pounds	Value, $							
2,789 (I)	1	70,000	6,667	16,665	86,665	27,890	20,000	10,000	57,890	28,775	10.32
3,160 (II)	1	70,000	6,667	16,665	86,665	31,600	20,000	10,000	61,600	25,065	7.93
3.422 (III)	1	70,000	6,667	16,665	86,665	34,220	20,000	10,000	64,220	22,445	6.56

The yields and values per ton have been calculated throughout on a basis of 90 per cent chemical extraction and 90 per cent mill recovery.

In Table II are given the approximate contents, values, and costs per gram of radium recovered, as calculated from the figures in Table I.

MARKET FOR RADIUM AND URANIUM, AND WORLD SUPPLY

RADIUM:

The world demand for radium for therapeutic purposes continues to be as insistent as ever, and can hardly be met owing to the extraordinarily small supply and the high price demanded. According to the latest volume of *Mineral Industry*, the price quoted in the United States during 1928 was $70,000 per gram. The same figure appeared throughout 1929 in the market quotations of *Engineering and Mining Journal*. This price, it may be noted, relates not to radium metal but to radium bromide, which is the form in which the element is employed. Figures of production, also, are understood to be in terms of this salt, and not of metallic radium.

Outside of its use in surgery and therapy, for which it is chiefly in demand, radium has also been employed to a considerable extent as an ingredient of luminous paint, used principally on the dials of instruments and watches. For this purpose, it is mixed with specially prepared crystalline zinc sulphide, in the proportion of 0.1 to 0.25 mg. of radium to 1 gram of the sulphide. Owing to the attendant danger to workpeople employed in using such paint, which danger has recently received considerable publicity by actions for damages in the United States' courts, efforts have been made to have its use prohibited by law, and it is likely that action along such lines will be taken in all countries. A satisfactory substitute for radium for the above purpose has been found in mesothorium.

While no exact figures are available, it has been recently stated (1) that the total world supply of radium bromide existing and available for therapeutic purposes is only 300 grams, or a little over half a pound.

Most of the supply is now obtained from deposits in the Belgian Congo, which are operated by the Union Minière du Haut Katanga,

(1) Die Umschau, December 21st, 1929.

the ore being shipped to Belgium for the extraction of the radium. In 1928, this Company reported a production of 40 grams, which was double the amount produced in 1926. It is stated that the Belgian works are being enlarged to care for a further increased output, the Union Minière having adequate supplies of ore at their mines to produce on a much larger scale. Considerable secrecy seems to have attended the operations of this Company, and it has incurred much criticism on the score of maintaining a radium monopoly and charging exorbitant prices, out of all proportion to the cost of production, for a substance whose chief usefulness consists in the alleviation of human suffering. In a recent press article (1), the Union Minière has come out in its own defence and has endeavoured to show that since 1923, when it came into active production, it has repeatedly lowered its prices, and that it is due to its entry into the field that the former high price of $120,000 per gram, which obtained when the United States was the principal producer, has been reduced to the present level.

Prior to 1921, most of the radium production was supplied by American companies extracting the element from carnotite ore mined in Colorado and Utah; this ore was worked primarily for its vanadium content, the radium being recovered as a by-product. Owing to its low grade (about 2 to 5 per cent U_3O_8, as compared with 60 to 90 per cent in uraninite), production has gradually fallen off, and in 1928 no radium was isolated in the United States.

In Czechoslovakia, the present radium production is stated to be at the rate of about 3 grams per year. It is obtained from pitchblende, the same mineral that occurs in the Belgian Congo, and of which the Wilberforce ore is a crystallized variety. It was in this ore that the element radium was first detected by the Curies, and, prior to the development of carnotite mining in the United States, Czechoslovakia was the world's most important source of radium ore.

The total present annual world production of radium is thus practically confined to the Belgian Congo output of 40 grams and the 3 grams produced by Czechoslovakia. Allowing for a further small production from unrecorded sources, it would seem that the total world production is under 50 grams per year.

---

(1) The Montreal Daily Star, December 16th, 1929.

Deposits of radium-bearing minerals are known in a number of other countries, including Portugal, South Australia, Mexico, Madagascar, Transvaal, Cape Province, Russian Turkestan, England (Cornwall), etc. In some of these, development work has been conducted, but it is not known that any of the deposits have been shown to be rich enough to work under existing market conditions.

It has recently been reported that investigation of pitchblende deposits in the Transvaal, north of Johannesburg, has shown the existence of ore in commercial quantities; and it has even been stated that an annual production of 25 grams of radium may be expected from this source. The report, however, lacks official corroboration. It was also stated in 1929 that an English company had been formed to take over certain Czechoslovakian occurrences and the Cornish and South Australian deposits. The Turkestan occurrences, which have produced small amounts of ore, are now being further investigated by the Russian government.

The Katanga uraninite deposits, in the Belgian Congo, are at the present moment by far the most important occurrence of radium-bearing minerals known. They seem capable of a greatly-increased output and exercise complete control of the market. It is held, however, that every effort should be made to discover sources of radium within the Empire, and the results of the work now proceeding on the occurrence with which this paper deals will therefore be awaited with much interest.

The present situation with respect to radium has recently been reviewed by Professor R. B. Moore (1). He notes that, between 1915 and 1917, work of the U. S. Bureau of Mines on the extraction of radium from American carnotite ore showed that the element could be isolated from material carrying only between 2 and 3 per cent U_3O_8 at a cost of about $40 per milligram. Treating high-grade pitchblende, running 40 per cent or better U_3O_8, he estimates the cost of extraction from Congo ore at not over $10 per milligram, and a total cost of $15 to $18 per milligram to cover mining and extraction.

Professor Moore states that the amount of radium element extracted to date from American carnotite ore is almost 200 grams. Of this quantity, a large proportion was used for war purposes and

(1) Mining and Metallurgy, February, 1930, pp. 91-2.

a considerable amount, also, in luminous paint, so that probably less than 50 grams out of the 200 grams produced is presently efficiently available for cancer treatment.

Professor Moore's estimate of the total world supply of radium now available for medical purposes is about 250 grams, which, at an estimated average price paid of $90,000 per gram, represents the colossal sum of over $22,000,000 as the value of a little over half a pound of material.

Canada in 1926 imported radium to the value of $38,902; in 1927, $21,118; and in 1928, $17,590.

URANIUM:

The trade in uranium and uranium compounds is small, and it is difficult to obtain figures. Most of the supply of the element is marketed in the form of the oxide or other salts, principally the nitrate or sulphate, or as ammonium or sodium uranate.

In the form of the metal, uranium finds its principal use as ferro-uranium, an alloy employed, either alone or in conjunction with tungsten, for hardening and toughening steel. Uranium carbide has been used to a limited extent as a pyrophoric agent, and as a catalyst in the manufacture of ammonia.

Various uranium salts are used in the porcelain and glass industries to impart a yellow, opalescent colour. In the textile trade, such salts find employment as mordants in silk, wool, and calico printing; and in the dye industry, in conjunction with potassium ferrocyanide, to produce brown shades. Uranyl nitrate and acetate are employed as reagents in the chemical laboratory. Uranium salts are also used in photography.

As regards the world production of uranium, statistics are reported in such various terms as to be comparatively useless in many cases as the basis of a market survey. However, the bulk of the supply may be taken as derived from the Belgian Congo and Czechoslovakia. In 1928, Belgium reported exports of uranium oxide (presumably all produced from Congo ores) totalling 84 long tons, and Czechoslovakia a production of 19 long tons. France, in 1927, reported exports of 18 long cwt. of uranium oxide and other uranium salts, presumably produced from imported ore, possibly from Portugal or Madagascar. The above 1928 figures show a total trade in uranium compounds of 104 long tons.

Countries reporting a production or exports of uranium minerals in recent years include: Portugal, with exports of 529 long tons in 1926, and 296 tons in 1927; Madagascar, with a production of 5 tons in 1926; and Russia, with a production of 35 tons in 1926 and 53 tons in 1927. The United States reported a production of a few tons in 1928.

The Portugese ore is believed to carry principally the minerals torbernite and autunite, which are, respectively, the phosphate of copper and uranium and of calcium and uranium. These minerals usually occur as alteration products of pitchblende. The Madagascar shipments consisted chiefly of the minerals euxenite and betafite, which are complex compounds of the rare earths and uranium. The Russian production is presumed to consist entirely of tyuyamunite, a uranovanadate of calcium, akin to carnotite, mined in Turkestan and treated at the Russian government radium extraction plant at Kame. The United States output was made up of carnotite, a mixture of vanadium, uranium, and potassium oxides, and torbernite and autunite, the first-named mined in Colorado and Utah, and the last two in New Mexico.

The commercial importance of the minerals mentioned above as either a present or a potential source of uranium is small, and they could hardly be considered as capable of supplying any large amount of the element unless found in deposits much richer than any yet known. The same holds good for the many known occurrences of pegmatitic uranium-rare-earth minerals throughout the world, and thus the market for uranium will almost certainly continue to be supplied in the main from deposits of pitchblende (uraninite).

In 1928, imports of uranium oxide and salts of uranium into the United States totalled 165,378 pounds, valued at $145,557. These figures show a very large increase—of nearly 100,000 pounds in quantity and more than $86,000 in value—over those for 1927.

SUMMARY

There exists on the Richardson property near Wilberforce, in Cardiff township, Ont., a deposit of radium-bearing ore, larger than anything of the kind hitherto known in Canada, and which development work done during 1929 suggests has commercial possibilities.

The ore is uraninite (the crystallized form of pitchblende) disseminated in the form of large crystals and lumps in a lead of calcite and fluorite, which also carries large crystals of apatite. This lead is believed to have a length of at least 500 feet, and its width ranges from 5 to 12 feet.

The deposit is well situated in respect both to ease of mining and to transportation. The ore is soft and easily crushed; and concentration is readily effected by tabling, followed by magnetic separation of the associated magnetite and re-tabling of the uraninite tailing. Much of the contained uraninite, also, can be recovered by hand-picking of the crude ore.

Tests by the Mines Branch on a carload shipment of ore showed that 1 gram of radium, worth at the current market price $70,000, would be recoverable from the concentrates obtained from 3,422 tons of ore, allowing a loss of 10 per cent in chemical treatment. The U_3O_8 content of the concentrates obtained from 1 ton of ore was 2.56 pounds.

Uraninite is the richest ore of radium known and is the material from which the bulk of the world's supply of this element has been obtained. Similar ore is being mined at the present time in the Belgian Congo and in Czechoslovakia, and is treated chemically for the isolation of the contained radium.

The present world supply of radium (in the form of radium salts) is stated to be about 300 grams, and this amount is being increased at the rate of probably less than 50 grams annually.

* * *